

The first light-curve analysis of eclipsing binaries observed by the INTEGRAL/OMC

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Abstract

Three Algol-type binaries in Cygnus constellation were selected for an analysis from a huge database of observations made by the INTEGRAL/OMC camera. These data were processed and analyzed, resulting in a first light-curve study of these neglected eclipsing binaries. The temperatures of the primary components range from 9500 K to 10500 K and the inclinations are circa 73° (for PV Cyg and V1011 Cyg), while almost 90° for V822 Cyg. All of them seem to be main-sequence stars, well within their critical Roche lobes. Nevertheless, further detailed analyses are still needed.

Key words: stars: binaries: eclipsing, stars: individual: PV Cyg, V822 Cyg, V1011 Cyg, stars: fundamental parameters

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1 Introduction

The INTEGRAL (INTERnational Gamma-Ray Astrophysics Laboratory) satellite was launched on 17 October 2002. Since then, there were many observations of the gamma-ray and X-ray sources obtained. Thanks to the OMC (Optical Monitoring Camera), there was collected also a large database of the observations in the visual passband.

For a detailed description of the camera, its efficiency and parameters, see e.g. Mas-Hesse et al. (2004). Due to its relatively large field of view (almost 5 × 5 degrees) there were observed also many photometric variable stars near the gamma and X-ray sources as a by-product. The main advantage of the OMC data is the duration of the continuous time series of observations, which could reach up to a few days without any interruption. This could not be achieved by the ground-based telescopes. Due to this fact, there could be discovered also very slow variables, or the minima of very slow Algol-type eclipsing binaries (hereafter EBs) could be caught during one observation run.

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Despite the fact that the older OMC observations are available on the internet¹, the data mining and the analysis are still very rare. Regarding the EBs, there were only one paper about the system V435 Cas (see Sokolovsky 2007) and the collection of 236 minima timings of EBs by Sobotka (2007). The analyses of the light curves of eclipsing binaries have not been published so far.

2 Analysis of the individual systems

All observations of the selected systems were carried out by the same instrument (50mm OMC telescope) and the same filter (Johnson's V filter). Time span of the observations ranges from November 2002 to July 2006. A transformation of the time scale has been done following the equation $JulianDate - ISDCJulianDate = 2,451,544.5$. Only a few outliers from each data set were excluded. The PHOEBE programme (see e.g. Prša & Zwitter 2005), based on the Wilson-Devinney algorithm (Wilson & Devinney, 1971), was used.

Due to the missing information about the stars, and having only the light curves in one filter, many of the parameters have to be fixed. At first, the temperature of the secondary component was fixed (according to the estimated spectral type). The "Detached binary" mode was used for computing and the eccentricity was set to 0 (circular orbit). The limb-darkening coefficients were interpolated from van Hamme's tables (see van Hamme 1993). The values of gravity brightening and bolometric albedo coefficients were set at their suggested values for convective atmospheres (see Lucy 1968), i.e. $G_1 = G_2 = 0.32$, $A_1 = A_2 = 0.5$. No third light was assumed: $l_3 = 0$.

2.1 PV Cyg

The first system is PV Cyg (= AN 93.1928 = GSC 03137-03117, $R.A. = 19^{\text{h}}\ 56^{\text{m}}\ 29^{\text{s}}$, $Decl. = +37^{\circ}\ 43' 08''$, J2000.0, $B_{max} = 12.7$ mag). This star was discovered to be a variable by Baade (1928) and its designation as PV Cyg was introduced by Guthnick & Prager (1933). Since then, there was no detailed analysis of the system performed, only the times of minima observations were published. The only rough estimation of its spectral types as A1+[G6IV] were published by Svechnikov & Kuznetsova (1990), but it is not very reliable.

According to these spectral types, the temperature of the primary should be circa 9100 K and the temperature of the secondary about 5700 K (according to Harmanec 1988). Due to this fact, the temperature of the secondary was fixed $T_2 = 5700$ K and T_1 was calculated (from its starting value 9100 K). The final fit is plotted in Fig.1, while all the relevant parameters of the fit are presented in Table 1. In this table the ephemeris JD_0 and P are written together with the inclination i , the mass ratio q , the radii ratio r_1/r_2 , the temperature ratio T_1/T_2 , the luminosity ratio L_1/L_2 and the Kopal's potentials Ω_i , respectively.

¹ see <https://sdc.laeff.inta.es/omc>

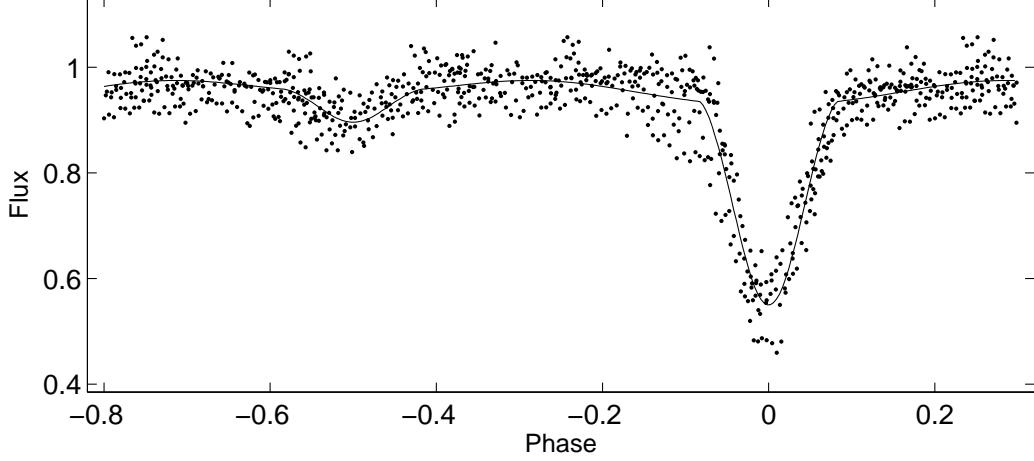


Fig. 1. The V light curve of PV Cyg.

Altogether there were obtained 795 observations of the star. As one can see from Table 1, the radius of the secondary is larger than the radius of the primary. Despite this fact, thanks to the higher effective temperature of the primary, the relative luminosity of the primary component is about 4 times larger. The scatter of the individual measurements is quite high, but the final fit is satisfactory.

2.2 V822 Cyg

The eclipsing binary V822 Cyg (= AN 216.1935, $R.A. = 19^{\text{h}} 54^{\text{m}} 08^{\text{s}}$, $Decl. = +36^{\circ} 21' 00''$, J2000.0, $B_{\text{max}} = 12.9$ mag) was discovered by Morgenroth (1935). The light curve was observed and published by Miller & Wachmann (1959), but any analysis has been performed, so its parameters are still questionable. Svechnikov & Kuznetsova (1990) published the first approximate estimation of the spectral types, resulting in (A3)+[G2IV]. But this result is again not very reliable.

From these spectral types one could derive the temperatures $T_1 = 8600$ K and $T_2 =$

Table 1

The light-curve parameters for PV Cyg, V822 Cyg and V1011 Cyg, respectively.

Parameter	PV Cyg	V822 Cyg	V1011 Cyg
JD_0 [HJD]	2452595.252 ± 0.002	2452595.910 ± 0.002	2452598.790 ± 0.001
P [day]	1.3148811 ± 0.0000003	1.2677742 ± 0.0000004	3.2393920 ± 0.0000002
i [deg]	73.1 ± 1.2	89.8 ± 2.1	72.5 ± 0.9
$q_{ph} = M_2/M_1$	0.53 ± 0.05	0.35 ± 0.03	0.52 ± 0.09
r_1/r_2	0.71 ± 0.03	1.10 ± 0.01	0.54 ± 0.04
T_1/T_2	1.63 ± 0.06	1.99 ± 0.08	1.87 ± 0.10
L_1/L_2	4.08 ± 0.21	9.20 ± 0.30	3.66 ± 0.08
Ω_1	4.83 ± 0.11	3.14 ± 0.03	6.11 ± 0.24
Ω_2	2.89 ± 0.05	2.44 ± 0.02	2.82 ± 0.19

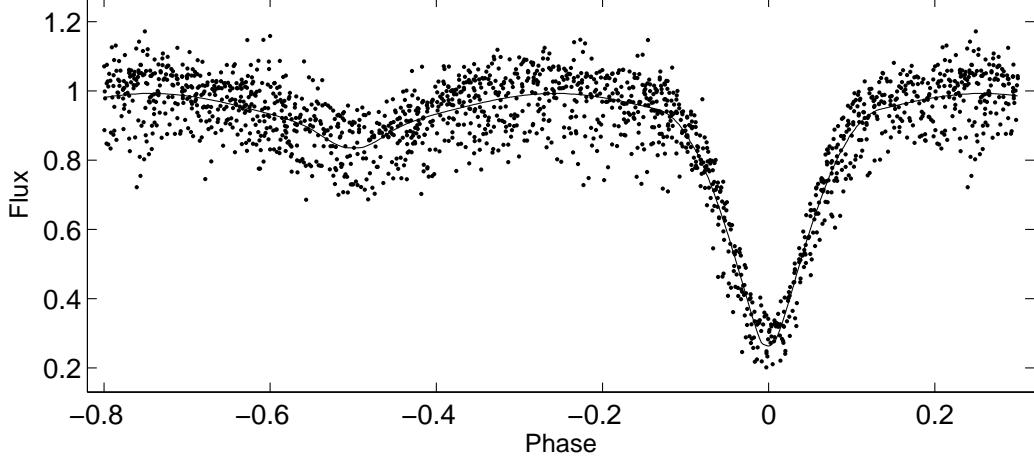


Fig. 2. The V light curve of V822 Cyg.

5900 K (according to Harmanec 1988). Exactly the same method as in the previous case was used. Altogether there are 1680 observations of V822 Cyg. The resulting parameters are in Table 1 and the plot is in Fig.2.

Although the scatter of the measurements is rather high, thanks to the relatively large number of observations (1855 in total), the final fit is satisfactory and no other effects are observable in this light curve.

2.3 V1011 Cyg

The last eclipsing binary selected for a detailed analysis is V1011 Cyg (= GSC 02677-01203, $R.A. = 19^{\text{h}} 55^{\text{m}} 15^{\text{s}}$, $Decl. = +34^{\circ} 12' 30''$, J2000.0, $B_{\max} = 12.2$ mag). It was discovered to be a variable by Wachmann (1961). The spectral type A0 was presented in Brancewicz & Dworak (1980), while more detailed classification as A0+[G3IV] was presented in Svechnikov & Kuznetsova (1990).

According to this latter paper, the proposed temperature of the primary is circa 9400 K, and about 5800 K of the secondary. Altogether there are 1704 observations. As one can see, the curve is not symmetric and the brightnesses near the phase -0.1 and near the phase 0.1 are not equal. This could be explained e.g. by the presence of a spot. If one assume the spot to be located on the primary component, the parameters of such a spot are the following:

Parameter	Value
Latitude [rad]	2.3 ± 0.9
Longitude [rad]	5.61 ± 0.44
Radius [rad]	0.25 ± 0.04
$T_{\text{spot}}/T_{\text{surface}}$	1.7 ± 0.3

The final parameters of the light-curve fit are presented in Table 1 and the fit itself is plotted in Fig.3. The 3-D plot of the system is shown in Fig.4.

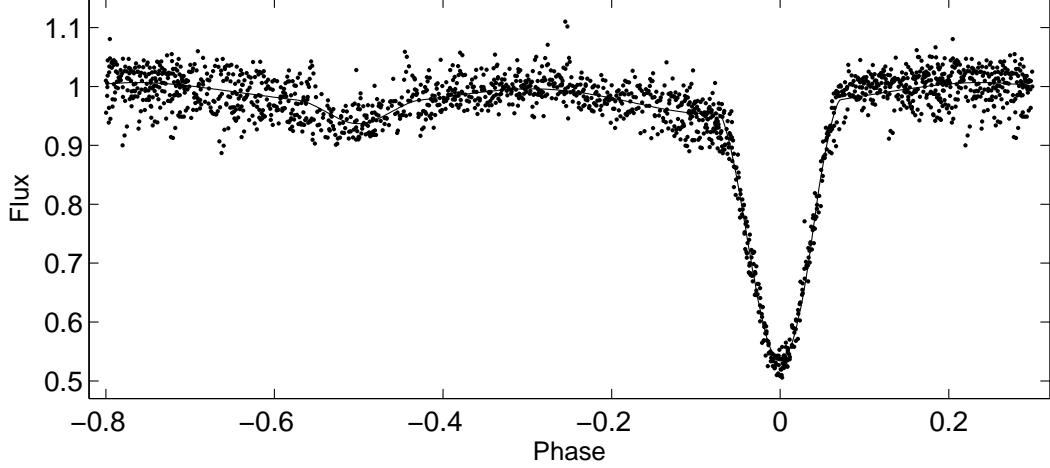


Fig. 3. The V light curve of V1011 Cyg.

However, the presence of spot on the primary is not able to describe the light curve in detail and at least two spots are needed. One of them should be brighter and the other one dimmer than the surface of the star. There is a slight difference between the shapes of the light curves obtained at different epochs. The first observations from 2002 show larger difference in brightness near the phase -0.1 and 0.1, while the observations from the following years show almost symmetric curve. This could indicate the time evolution of the spots. Only further analysis would confirm the presence of the spots and their possible evolution.

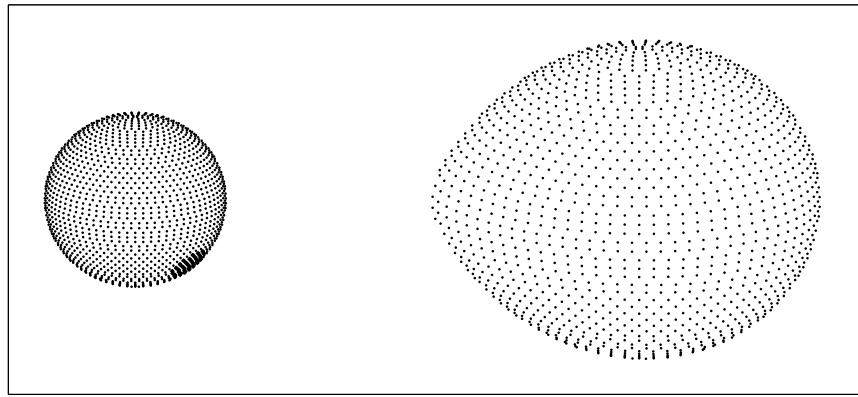


Fig. 4. The 3-D plot of V1011 Cyg at the phase 0.25, primary is the left one.

3 Discussion and conclusions

The light-curve analysis of three selected systems in Cygnus constellation has been done. Using the light curves observed by the INTEGRAL satellite, one can estimate the basic physical parameters of these systems. Despite this fact, the parameters are still only the preliminary ones, affected by relatively large errors and many of the relevant parameters were fixed at their suggested values. The detailed analysis is still needed, especially in different filters. Together with a prospective radial-velocity study, the final picture of the systems could be done. Particularly, the system V1011 Cyg seems to be the most interesting one due to its asymmetric light curve.

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References

- Baade, W. 1928, Astronomische Nachrichten, 232, 65
Brancewicz, H. K., & Dworak, T. Z. 1980, Acta Astronomica, 30, 501
Guthnick, P., & Prager, R. 1933, Astronomische Nachrichten, 249, 253
Harmanec, P. 1988, Bulletin of the Astronomical Institutes of Czechoslovakia, 39, 329
Lucy, L. B. 1968, ApJ , 151, 1123
Mas-Hesse, J. M., Giménez, A., Domingo, A., Rísquez, D., Caballero, M. D., Gutiérrez, R., Solano, E., & the OMC team 2004, 5th INTEGRAL Workshop on the INTEGRAL Universe, 552, 729
Miller, W. J., & Wachmann, A. A. 1959, Ricerche Astronomiche, 6, 153
Morgenroth, O. 1935, Astronomische Nachrichten, 256, 281
Prša, A., & Zwitter, T. 2005, ApJ , 628, 426
Svechnikov, M. A., & Kuznetsova, E. F. 1990, Sverdlovsk : Izd-vo Ural'skogo universiteta, 1990
Sobotka, P. 2007, Informational Bulletin on Variable Stars, 5809, 1
Sokolovsky, K. V. 2007, Peremennye Zvezdy Prilozhenie, 7, 30
van Hamme, W. 1993, AJ , 106, 2096
Wachmann, A. A. 1961, Astronomische Abhandlungen der Hamburger Sternwarte, 6, 1
Wilson, R. E., & Devinney, E. J. 1971, ApJ , 166, 605